CLAIMS

What is claimed is:

1. An apparatus for calibrating a machine measuring system that has a first measuring device and a second measuring device, the apparatus comprising:

a first calibration target mounted in a predetermined relationship to the first measuring device of the machine measuring system;

a third measuring device mounted in a predetermined relationship to the second measuring device of the machine measuring system; and

a data processor configured to calculate a relative measuring-device position value of the machine measuring system based on a relative position of the first calibration target to the third measuring device; wherein the relative measuring-device position value of the machine measuring system represents the position of the first measuring device relative to the second measuring device.

2. An apparatus as recited in Claim 1, wherein each measuring device is selected from a group consisting of:

an image-capturing device configured to capture images for use in calculating the relative measuring-device position value of the machine measuring system;

a gravity gauge configured to detect movement of one or more other measuring devices with respect to another measuring device or with respect to a fixed point;

a string gauge configured to detect movement of one or more other measuring devices with respect to another measuring device or with respect to a fixed point; and

a light source located near one measuring device to direct a light beam at a detector that is located near another measuring device.

3. An apparatus as recited in Claim 1, wherein, in operation:

a value that represents the position of the first calibration target relative to the third measuring device is stored as a calibration value;

the third measuring device is configured to periodically measure a new value that represents a new position of the first calibration target relative to the third measuring device; and

if the calibration value differs from the new value beyond an acceptable amount, then an alert alarm is raised.

4. An apparatus as recited in Claim 3:

wherein, in operation, the difference in the calibration value and the new value is used in updating the relative measuring-device position value of the machine measuring system.

5. An apparatus as recited in Claim 3:

wherein, in operation, upon recognizing that the calibration value differs from the new value beyond an acceptable amount, the relative measuring-device position value of the machine measuring system is recalculated.

6. An apparatus as recited in Claim 1, wherein, in operation:

a value that represents the position of the first calibration target relative to the third measuring device is stored as a calibration value;

a new value that represents the position of the first calibration target relative to the third measuring device is periodically measured; and

if the calibration value differs from the new value beyond an acceptable amount, then an alert alarm is raised.

7. An apparatus as recited in Claim 1, wherein the data processor is further configured to compute the relative measuring-device position value of the machine measuring system based on:

a relative measuring-device position value that represents a position of the second measuring device with respect to the third measuring device, and

a relative measuring-device target position value that represents a position of the first measuring device relative to the first calibration target.

8. An apparatus as recited in Claim 7, wherein, in operation, the relative measuring-device target position value that represents the position of the first measuring device relative to the first calibration target is computed based on a position of the first calibration target relative to a second calibration target.

9. An apparatus as recited in Claim 8, wherein, in operation, the position of the first calibration target relative to the second calibration target is obtained by using a fourth measuring device which provides information to calculate the position of the first calibration target relative to the second calibration target.

10. An apparatus as recited in Claim 8, wherein, in operation:

the position of the first calibration target relative to the second calibration target is obtained by an image-capturing device;

images of the first calibration target and the second calibration target are provided by the first calibration target and the second calibration target positioned in the view of the image-capturing device; and

the images of the first calibration target and the second calibration target are input into the data processor to calculate the relative position of the first calibration target to the second calibration target.

11. An apparatus as recited in Claim 1, wherein the data processor is further configured to compute the relative measuring-device position value of the machine measuring system while the first measuring device and the second

measuring device of the machine measuring system are measuring targets of objects under measurement.

12. An apparatus as recited in Claim 1, wherein the data processor is further configured to:

compute a modified relative measuring-device position value of the machine measuring system while the first measuring device and the second measuring device of the machine measuring system are measuring targets of objects under measurement, and

modify measurements produced by measuring the targets of objects under measurement based on the modified relative measuring-device position value of the machine measuring system.

13. An apparatus as recited in Claim 12, wherein the data processor is further configured to modify measurements produced by measuring the targets of objects under measurement based on the modified relative measuring-device position value of the machine measuring system only when the modified relative measuring-device position value differs from the relative measuring-device position value by more than a predetermined value.

14. An apparatus as recited in Claim 1, wherein the machine measuring system is one in which each of the first measuring device, the second measuring device, and the third measuring device is an image-capturing device that performs measurements of objects by capturing images.

15. An apparatus as recited in Claim 1, wherein the machine measuring system is one in which any one of the first measuring device, the second measuring device, and the third measuring device is an image-capturing device that performs measurements of objects by capturing images.

16. An apparatus for calibrating a machine measuring system that has a first measuring device and a second measuring device, the apparatus comprising:

calibration means mounted in a fixed relationship to at least the first measuring device for detecting change in position of the second measuring device relative to the first measuring device;

a data processor configured to measure the position of the first measuring device relative to the second measuring device, based on pre-determined information specifying a position of the first measuring device relative to the calibration means, and based on information received from the calibration means that indicates a change in position of the second measuring device relative to the first measuring device.

17. An apparatus as recited in Claim 16, wherein the calibration means comprises a light source mounted in fixed relationship to the first measuring device and a light detector mounted in fixed relationship to the second measuring device and having an output coupled to the data processor.

18. An apparatus as recited in Claim 16, wherein the calibration means comprises a linear movement gauge, a first string having a proximal end mounted in fixed relationship to the first measuring device and a distal end affixed to the linear movement gauge, and a second string having a proximal end affixed to the linear movement gauge and a distal end mounted in fixed relationship to the second measuring device.

19. A measurement apparatus comprising:

a plurality of devices under measurement; and

a plurality of means for measuring the relative positions of the plurality of devices;

wherein the means for measuring a position of a first device of the plurality of devices relative to a second device of the plurality of devices includes:

a calibration device mounted near the first device in which the position of the calibration device relative to the first device is predetermined;

a calibration target mounted near the second device in which the position of the calibration target relative to the second device is predetermined;

means for measuring the position of the calibration device relative to the calibration target; and

means for measuring the position of the first device relative to the second device based on:

(1) the position of the calibration device relative to the first device;

(2) the position of the calibration target relative to the second device; and

(3) the position of the calibration device relative to the calibration target.

20. An apparatus as recited in Claims 19 wherein the calibration device constitutes the means for measuring the position of the calibration device relative to the calibration target.

---

21. A method for calibrating a machine measuring system that has a first measuring device and a second measuring device, the method comprising the steps of:

mounting a first calibration target in a predetermined relationship to the first measuring device of the machine measuring system;

mounting a third measuring device in a predetermined relationship to the second measuring device of the machine measuring system; and

calculating a relative measuring-device position value of the machine measuring system representing the position of the first measuring device relative to the second measuring device based on a position of the first calibration target relative to the third measuring device.

22. A method as recited in Claim 21, including selecting each measuring device from a group consisting of

an image-capturing device configured to capture images for use in calculating the relative measuring-device position value of the machine measuring system;

a gravity gauge configured to detect movement of one or more other measuring devices with respect to another measuring device or with respect to a fix point;

a string gauge configured to detect movement of one or more other measuring devices with respect to another measuring device or with respect to a fix point;

a light source located near one measuring device to direct a light beam at a detector that is located near another measuring device.

23. A method as recited in Claim 21, including storing a value that represents the position of the first calibration target relative to the third optical sensor measuring device as a calibration value; wherein

the third measuring device periodically measures a new value that represents a new position of the first calibration target relative to the third measuring device; and

if the calibration value differs from the new value beyond an acceptable amount, then raising an alert alarm.

24. A method as recited in Claim 23, including applying the difference in the calibration value and the new value to update the relative measuring-device position value.

25. A method as recited in Claim 23 including, upon recognizing that the calibration value differs from the new value beyond an acceptable amount, recalculating the relative measuring-device position value.

26. A method as recited in Claim 21, including:

storing a value that represents the position of the first calibration target relative to the third measuring device as a calibration value;

periodically measuring a new value that represents the position of the first calibration target relative to the third measuring device; and

if the calibration value differs from the new value beyond an acceptable amount, then raising an alert alarm.

27. A method as recited in Claim 21, further comprising the step of computing the relative measuring-device position value of the machine measuring system based on:

a first relative measuring-device position value that represents a position of the second measuring device relative to the third measuring device, and

a second relative measuring-device target position value that represents a position of the first measuring device relative to the first calibration target.

28. A method as recited in Claim 27, wherein the second relative measuring-device target position value is computed based on a position of the first calibration target relative to a second calibration target.

29. A method as recited in Claim 28, wherein the position of the first calibration target relative to the second calibration target is obtained by using a fourth measuring device which provides information to calculate the position of the first calibration target relative to the second calibration target.

30. A method as recited in Claim 28 wherein:

the position of the first calibration target relative to the second calibration target is obtained by using an image-capturing device;

images of the first calibration target and the second calibration target are provided by placing the first calibration target and the second calibration target in the view of the image-capturing device; and

the images of the first calibration target and the second calibration target are applied to calculate the position of the first calibration target relative to the second calibration target.

31. A method as recited in Claim 21, further comprising the step of computing the relative measuring-device position value of the machine measuring system while the first measuring device and the second measuring device of the machine measuring system are measuring targets of objects under measurement.

32. A method as recited in Claim 21, further comprising the steps of:

computing a modified relative measuring-device position value of the machine measuring system while the first measuring device and the second measuring device of the machine measuring system are measuring targets of objects under measurement, and

modifying measurements produced by measuring the targets of objects under measurement based on the modified relative measuring-device position value of the machine measuring system.

33. A method as recited in Claim 32, wherein the step of modifying measurements produced by measuring the targets of objects under measurement based on the

modified relative measuring-device position value of the machine measuring system is performed only when the modified relative measuring-device position value differs from the relative measuring-device position value by more than a predetermined value.

34. A method as recited in Claim 21, wherein each of the first measuring device, the second measuring device, and the third measuring device is an image-capturing device that performs measurements of objects by capturing images.

35. A method as recited in Claim 21, wherein any of the first measuring device, the second measuring device, and the third measuring device is an image-capturing device that performs measurements of objects by capturing images.

36. A method for calibrating a machine measuring system that has a first measuring device and a second measuring device, the method comprising the steps of:

mounting a calibration device in a fixed relationship to at least the first measuring device for detecting change of position of the second measuring device relative to the first measuring device; and

measuring the position of the first measuring device relative to the second measuring device based on predetermined information specifying a position of the first measuring device relative to the calibration device, and based on information received from the calibration device that indicates change of position of the second measuring device relative to the first measuring device.

37. A method as recited in Claim 36, wherein the step of measuring comprises the step of using a light source mounted in fixed relationship to the first measuring device and a light detector mounted in fixed relationship to the second measuring device to detect the change of position of the second measuring device relative to the first measuring device.

38. A method for measuring the relative positions of a plurality of devices, the method comprising the steps of:

for a position of a first device of the plurality of devices relative to a second device of the plurality of devices,

mounting near the first device a calibration device in which the position of the calibration device relative to the first device is predetermined;

mounting near the second device a calibration target in which the position of the calibration target relative to the second device is predetermined;

measuring the position of the calibration device relative to the calibration target; and

determining the position of the first device relative to the second device based on:

the position of the calibration device relative to the first device;

the position of the calibration target relative to the second device; and

the position of the calibration relative device to the calibration target.

39. A computer-readable medium bearing instructions for calibrating a machine measuring system that has a first measuring device and a second measuring device adapted to be mounted in a predetermined spatial relationship to each other, a first calibration target adapted to be mounted in a predetermined spatial relationship to the first measuring device, and a third measuring device adapted to be mounted in a predetermined spatial relationship to the second measuring device, the computer-readable medium comprising instructions for performing the steps of:

calculating a relative measuring-device position value of the machine measuring system based on a position of the first calibration target relative to the third measuring device, the relative measuring-

device position value of the machine measuring system representing the position of the first measuring device relative to the second measuring device.

40. A computer-readable medium as recited in Claim 39, further comprising instructions for performing the step of computing the relative measuring-device position value of the machine measuring system while the first measuring device and the second measuring device of the machine measuring system are measuring targets of objects under measurement.

41. A computer-readable medium as recited in Claim 39, further comprising instructions for performing the steps of:

computing a modified relative measuring-device position value of the machine measuring system while the first measuring device and the second measuring device of the machine measuring system are measuring targets of objects under measurement, and

modifying measurements produced by measuring the targets of objects under measurement based on the modified relative measuring-device position value of the machine measuring system.

42. A computer-readable medium as recited in Claim 41, wherein the step of modifying measurements produced by measuring the targets of objects under measurement based on the modified relative measuring-device position value of the machine measuring system is performed only when the modified relative measuring-device position value differs from the relative measuring-device position value by more than a predetermined value.

43. A computer-readable medium bearing instructions for calibrating a machine measuring system that has a first measuring device and a second measuring device adapted to be mounted in a predetermined spatial relationship to each other, and a

calibration device adapted to be mounted in a predetermined spatial relationship to at least the first measuring device for detecting change of position of the second measuring device relative to the first measuring device, the computer-readable medium comprising instructions for performing the steps of:

measuring the position of the first measuring device relative to the second measuring device based on predetermined information specifying a position of the first measuring device relative to the calibration device, and based on information received from the calibration device that indicates change of position of the second measuring device relative to the first measuring device.

add B1
add C5